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Structural and Stratigraphic Mapping of "Patty" Field, Onshore Niger Delta, Nigeria.

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Abstract: *Niger Delta is a wave-dominated Delta, aged between palaeogene to recent situated in the Gulf of Guinea and extending into the northern Joint Development Zone (JDZ).Oil and gas are predominantly trapped in sandstones and unconsolidated sands within the Agbada formation.Intensive exploratory work in and around Niger Delta has led to the discovery of notable fields, such as Bonga, Agbami/Ekoli and Akpo in Nigeria and Zafiro and Alba in Equatorial Guinea.Seismic data were integrated with well logs to define the subsurface geometry, stratigraphy and hydrocarbon trapping potential of "Patty" field. Lithologic units were identified on the logs and correlated across the wells. The stratigraphic cross-sections show a general lateral continuity of the lithological units across the field. The seismic-to-well ties result shows high amplitude reflection events which correspond to sand units, while low amplitude reflection events indicate shale units. Structural contour maps were generated for each of the three mapped horizons(H1, H2, and H3). Closures considered as good hydrocarbon prospects were delineated. Stratigraphic plays suspected includesunconformities, pinch-outs, four-way closure and sand lenses channels.The integration of seismic data with well logs proved to be a useful tool in structural and stratigraphic mapping and in predictingvertical and lateral variations in the lithological units.*

Key words: *Structural, Seismic,Stratigraphic, Well logs, Niger Delta, Patty.*

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I. INTRODUCTION

The Niger Delta is ranked themost significant delta in the West African continental margin and among the foremost prolific deltaic hydrocarbon provinces in the world. Oil and gas are primarily produced from sandstones and unconsolidated sands within the Agbada formation. The main objective of oil and gas exploration is identifying and delineatingthe extent structural and stratigraphic traps capable of holding economically exploitable accumulations for field appraisals and development.New advances and technologiesin seismic and borehole geophysics has made it possible to map very subtle and complexstructural and stratigraphic trapswith high degree of precision.Seismic profiles are capable ofrevealing lateral image of the subsurface geometry and estimate of the acoustic impedance which corresponds to the formation densities and layer velocities.Vertical details of the subsurfaceare limited due to lengthy duration of individual seismic wavelets and the case of overlapping wavelets from closely spaced reflectors. However, vertical resolution of the physio-chemical characteristics of geologic formations can be obtained from well logs. Although, well logs are limited in their definition of lateral variation of subsurface parameters due to its geometry and positions.Integration of seismic and well logs is very reliabletool for accurate mapping of complex structural and stratigraphic features(Barde *et al*., 2002, 2000; Adejobi and Olayinka, 1997), as lateral facies and vertical lithologicalchanges can easily be delineated. It helps to minimizes the risk associated with discovering oil and gas within subtle and complex structural/stratigraphic features. It helps to discriminate between poor and rich reservoirs. In this study, 3D seismic reflection data were integrated with well logs to characterize subsurface geometry and stratigraphy, determine hydrocarbon potential and delineate possible hydrocarbon prospects of "Patty" field in Niger Delta. Sixty-two 3-D seismic reflections lines was used (forty cross-lines shot parallel to the direction of dip and twenty-two in-lines shot parallel to the strike direction).

The Geology and Stratigraphy of Niger Delta

Niger Delta is situated at the apex of the Gulf of Guinea on the west coast of Africa, covering an area of about 75 000 km^2. The geology of the tertiary Niger Delta province has been described by several researchers (Short and Stauble, 1967; Weber, 1971; Weber and Daukoru, 1975; Weber *et al.*, 1978; Evamy *et al.*, 1978; Doust and Omatsola, 1990; Haack *et al.*, 2000). Basement tectonics related to crucial divergence and translation during the late Jurassic and Cretaceous continental rifting probably determined the original site of the main rivers that controlled the early development of the Delta. The Cenozoic development of the Delta is also believed to have taken place under approximate isostatic equilibrium. The main depocenter is thought to have been at the triple junction between the continental and oceanic crust where the delta reached a main zone of crustal instability. The Niger Delta is a large arcuate delta of the destructive, wave-dominated type and is composed of an overall regressive clastic sequence which reaches a maximum thickness of about 12 km in the basin center. The Delta's sediments show an upward transition from marine pro-delta shales (Akata Formation) through a paralic interval (Agbada formation) to a continental sequence (Benin formation). These three sedimentary environments, typical of most deltaic environments, extend across the whole delta and ranges in age from early tertiary to recent. A separate member, the Afam clay member of the Benin formation is recognized in the eastern part of the delta and is considered as an ancient valley fill formed in Miocene sediments. The formations are strongly diachronous (Murat, 1970) and cut across the time stratigraphic units which are characteristically S-shaped in cross-section. Most economically exploitable hydrocarbon in the delta is believed to be trapped within the Agbada formation.Structurally, the Niger Delta shelf developed as a prograding extensional complex overlying a ductile substrate which probably composed largely of over pressure marine shales. The onshore growth fault systems have been described by Doust and Omatsola (1990) as a series of major growth fault bounded depobelts or mega-structures thought to be transient basinal areas succeeding one another in space and time as the delta progrades southward. The extensional system is dominated by "tepee" structure in which landward-dipping growth faults intersects seawarddipping in complex interlocking fault networks (Figure 1). The most striking structural features of the Cenozoic Niger Delta complex are the syn-sedimentary structures which deform the delta largely beneath the Benin sand facies. These structures, regarded as the product of gravity sliding during the course of deltaic sedimentation, are polygenic in origin and their complexity increases generally in down delta direction (Merki, 1972). The synsedimentarystructures, called growth faults, are predominantly trending northeast to southwest and northwest to southeast (Hosper, 1971). Associated with these growth faults are rollover anticlines, shale ridges and shale diapers which are caused by shale upheaval ridges. Mud diapers are the most common and occur on the landward side of the growth faults restricting sedimentation on the up-thrown side of the faults and enhancing sedimentation on the down-thrown side. Most of the faults are listric normal; others include structure building growth faults, crestal faults, flank faults, counter regional faults and antithetic faults.

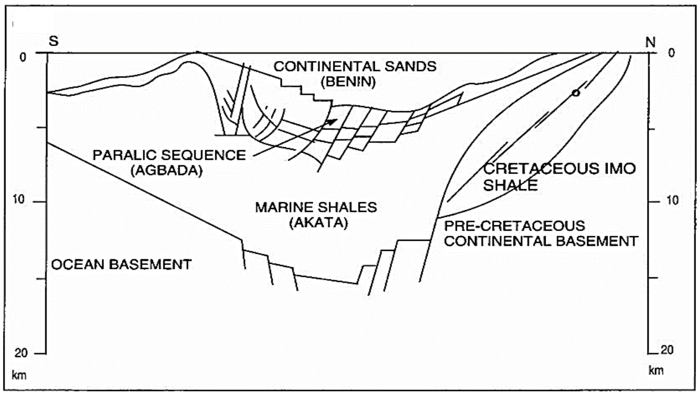

Figure 1: Axial Portion ofNiger Delta Showing the Relationships of the Tripartite Division of the Tertiary Sequence to Basement (Doust and Omatsola, 1990).

Oil and gas are predominantly trapped by rollover anticlines and fault closures. Stratigraphic traps ofpalaeo-channel fills, regional sand pinch-outs and truncations, crestal accumulations below unconformitysurfaces, cayon-fill accumulations above unconformity surfaces, incised valley and low-stand fans have been recognized (Orife and Avbovbo, 1982; Kruise and Idiagbor, 1994). Hydrocarbon distribution in the Niger Delta is complex, gas-to-oil ratio generally increases southward away from the depocentre within a depobelts (Evamy *et al.*, 1978) and is primarily controlled by thermal history of the source rocks, source rocks quality, migration and sealing quality. In addition, the timing of traps formation could be a factor that controls the distribution of hydrocarbon (Chukwueke, 1997).

Location and Geological Setting of "Patty" field

"Patty" field is located in the Northern Onshore Depo-belt of the Niger Delta at about 80 km North-East of Warri in Delta State (Figure 2). The field lies within the farm out area of marginal field, awarded to by the Nigerian government during the 2003 marginal fields licensing round.The field was discovered in 1966 and the structure was later appraised by an exploratory well. Nine hydrocarbon bearing reservoirs were encountered by the two wells drilled on the field.

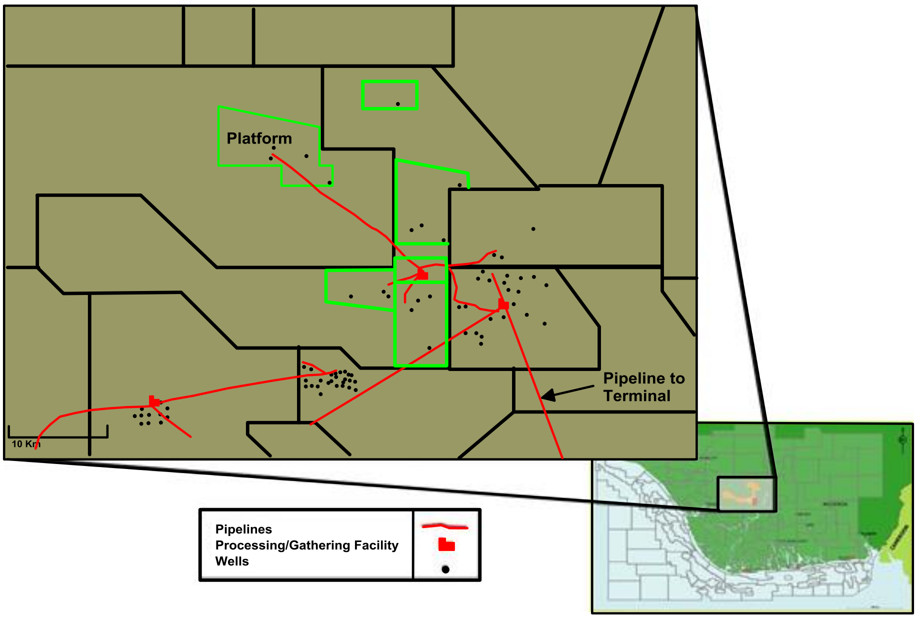

Figure 2: Location Map of the Study Area.

II. MATERIAL AND METHODOLOGY

Data used for this study include sixty-two 3-D seismic reflections lines which cover about 80 km^2 North-East of Warri in Delta State (Figure 2). Forty cross-lines shot parallel to the direction of dip and twenty-two in-lines shot parallel to the strike direction.Five well log data which consist of gamma ray, caliper, laterolog, dual laterolog(resistivity) and neutron-density logs etc. were also used for this study. Data were loaded into ©Petrel software andmap view was produced. This revealslocation ofeach well.The correlation was done to identify different lithologies (reservoirs sand top and base) and their various thickness (Figure 3).

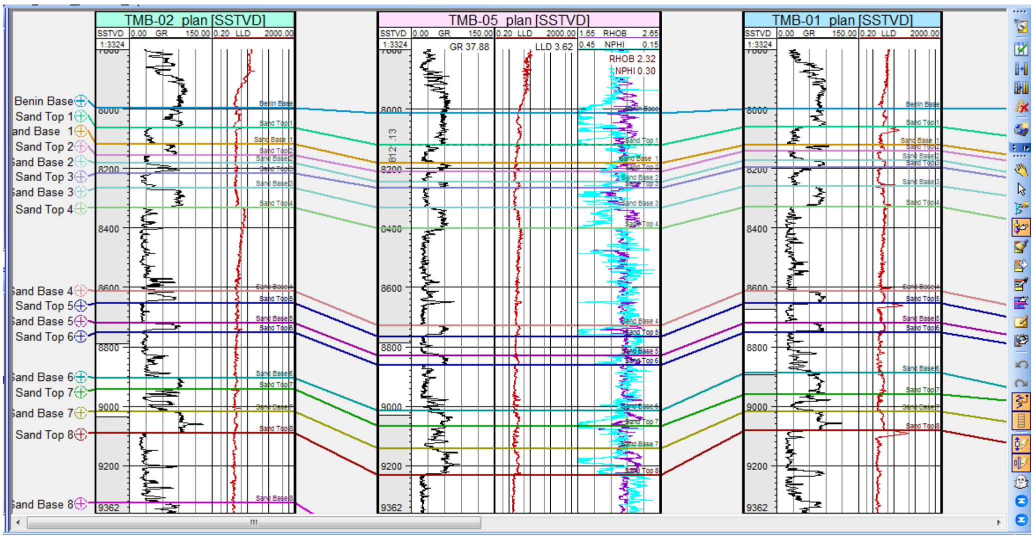

Figure 3: Sample of Well Correlation.

The seismic data was uploaded into the software and well was tied to seismic data (Figure 4). Fault digitization was carried out using a fault polygon (Figure 5).Faults are picked on the strike line because faults are perpendicular to the strike. This helps to delineate prominent faults across the sections. Seismic data was tied to well logs to correctly identify the position (subsurface depth) of the reflecting horizon. Tying of seismic data helps to accurately ensure that a trace of geologic surface interpreted on one line is the same surface interpreted on an intersecting line.This tool allows calibration interactive checkshot of log data, creation of analytical wavelet, extraction of statistical and deterministic wavelet, and generation of synthetic seismogram for 2D and 3D seismic data.

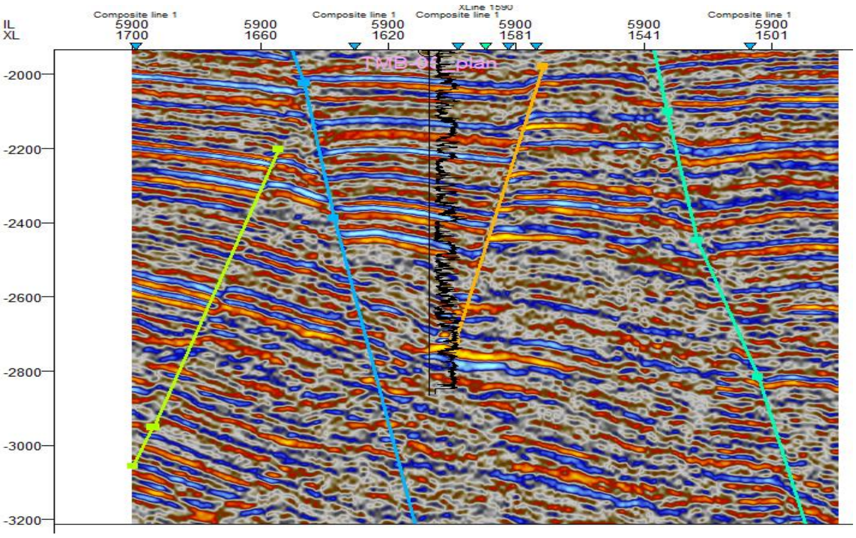

Figure4*:* Checkshots is Loaded

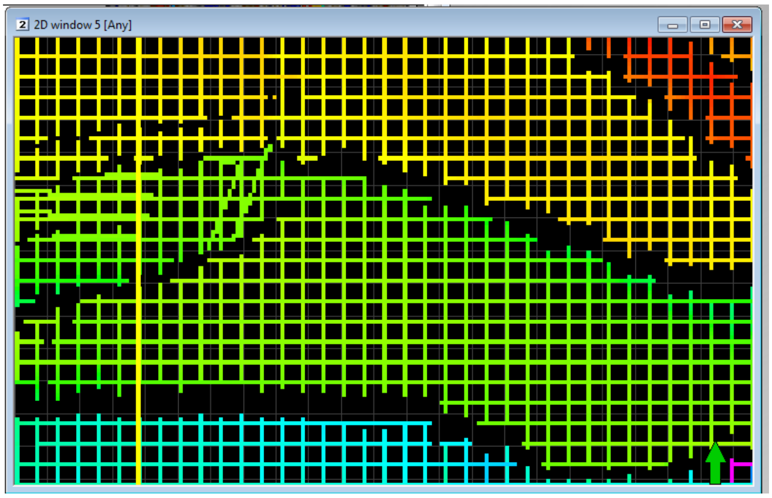

Figure 5*:* Fault Digitization

III. RESULTS AND DISCUSSION

Seismic Interpretations and Stratigraphic Cross-Sections

The migration of seismic sections allows for the tying of seismic sections at the intersection point between the cross-lines and in-lines. Majority of the prominent faults picked on the seismic records are counter regional growth faults which are characteristics of the selvedge, offshore Niger Delta (Ojo, 1996).Two regional growth faults F1 and F2 trending approximately north-south and dipping south-west and other minor fault F3, F4, F5 and F6 were delineated. The throw of the major faults ranges from 46 to 79 m (150 to 260 ft), while that of the minor faults ranges from 24 to 36 m (80 to 120 ft). This throw is appreciable and capable of producing migration pathway for hydrocarbon.The horizons mapped are laterally continuous on the seismic records and formed a closed loop along the tie lines.The structure contour maps of the horizons mapped, “Sand E” and “Sand F”are presented in Figures 6and7 respectively.A map view of 3D Window was also generated (Figure 8). It shows a system of rollover anticlines associated with growth faults. The faults appeared crescent-shaped with the concave side being towards the down-thrown block. The crestal faults (synthetic and antithetic) show less curvature in the horizontal plane and are generally steeper in the vertical plane. The throw of the major faults ranges from 46 to 79 (150 ft to 260 ft). The growth faults are sub-parallel to one another and strikes in the west-east direction. The faults are sealing on the up-thrown side of the fault zone where most of the hydrocarbons could be trapped (Figure 9). The faults may have serves as migratory paths for hydrocarbon into the structural closures and the reservoir units at large. Cross-sections through its structure maps also suggest a system of growth faults, roll over anticlines and folding. These closures serve as good traps for hydrocarbon and are therefore possible hydrocarbon prospects.

Figure6: Subsurface Map (Sand E)

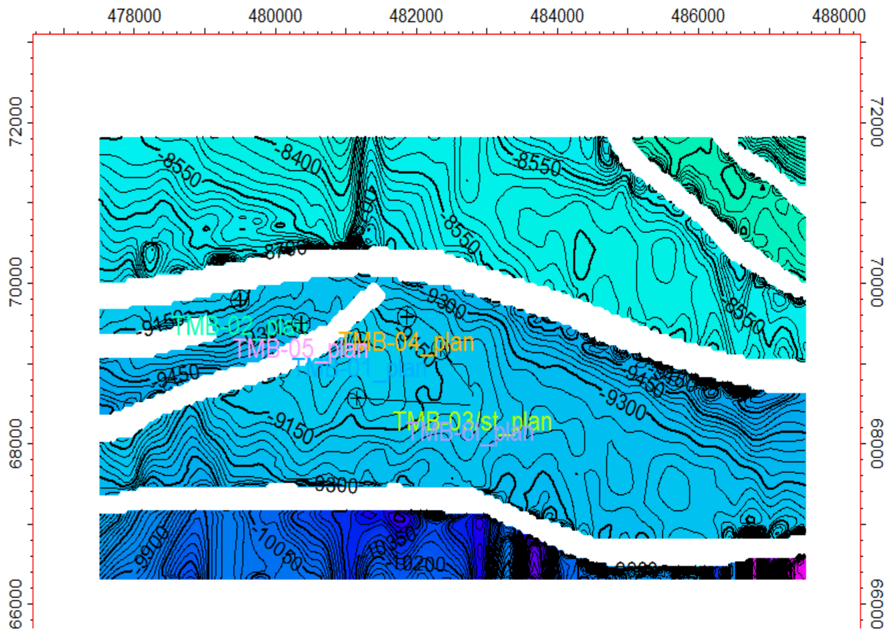

Figure 7: Sand F-Subsurface Map(Depth)

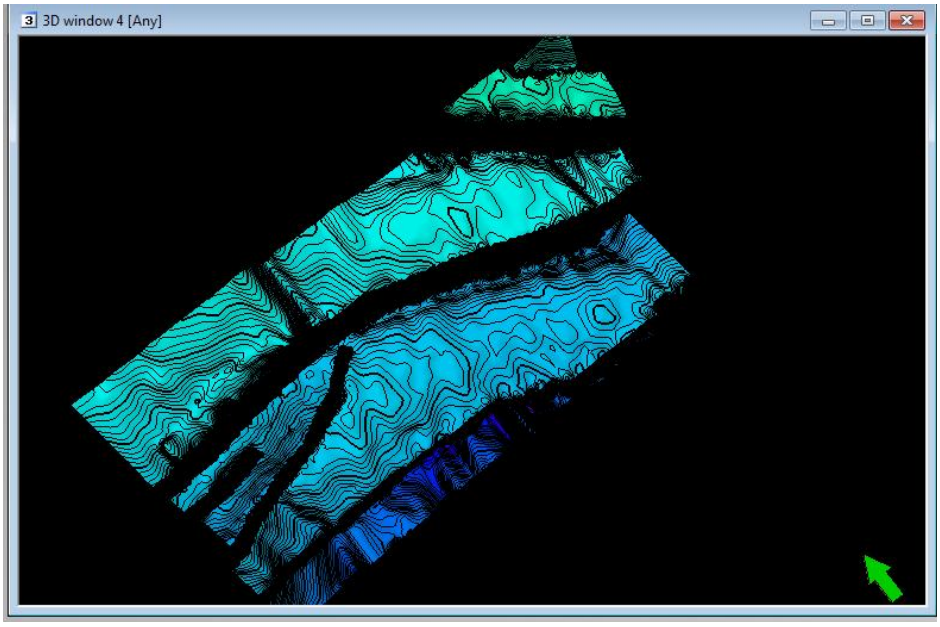

Figure8: Map View On 3D Window

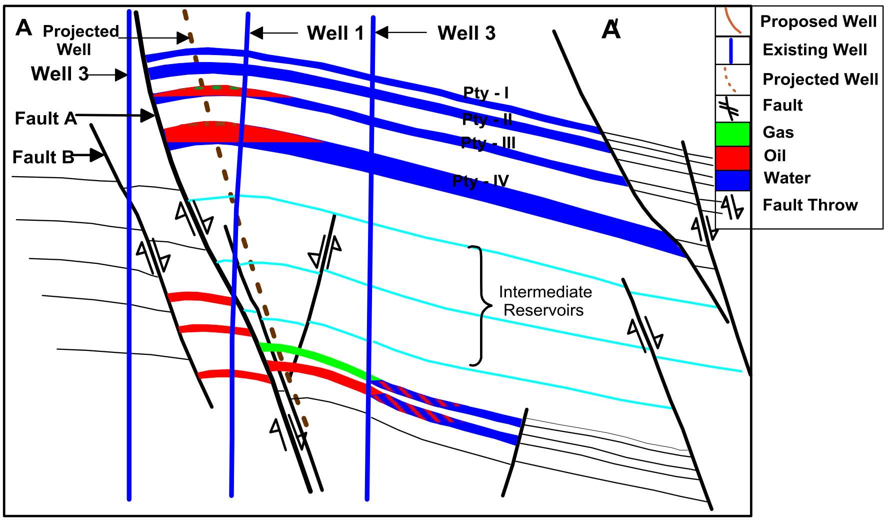

Figure 9: Schematic Cross-Section showing Structural Features and Field Reservoirs.

IV. CONCLUSIONS AND RECOMMENDATION

The result of the stratigraphic cross-sections drawn shows that the horizons (bright spot) are laterally continuous, however, pinch-outs/wedge-outs are evident. The horizons mapped are all within the Agbada formation, where most of the hydrocarbon is believed to be trapped in the Niger Delta. Anticlinal closures and fault assisted closures regarded as good hydrocarbon prospect areas have been delineated in the structure contour maps. Trapping of hydrocarbon by means of simple closure is independent of the presence of faults and trapping in fault closures. It is assisted by sealing faults, meanwhile the fault plane and the sediments dip in opposite directions. Apart from the structural traps delineated, other stratigraphic plays including pinchouts, sand lenses and channels were also suspected. The integration of seismic data and well logs proved to be a useful and valid tool in structure and stratigraphic mapping.The integration of seismic data with well logs was successful in defining the subsurface geometry, stratigraphy and hydrocarbon trapping potential of the field. The technique proved to be useful in structural and stratigraphic mapping and in predicting lateral and vertical variations in the lithologic units reasonably. Hydrocarbon prospect areas were delineated in the structural maps produced. The growth faults may have acts as migratory paths for hydrocarbon from the underlying Akata formation. Thus, it is necessary to integrate all exploration and evaluation tools so as to effectively explore the study area and optimize well locations. Amplitude variation with offset (AVO), seismic attributes analysis and seismic inversion should be carried out in the study area to better discriminate the lithology, characterize the reservoirs and define the hydrocarbon types.

In addition, more wells should be drilled within this Field toprovide drainage points for reservoirs identified and to develop part of theundeveloped Reserves. It will also provide structural control to further investigate sand development of thehanging wall structure in near crestal positions and resolve fluid type variations seen in the offset wells.

Conflict of Interest
There is no conflict of interest about this work.

Funding Statement
Data used in this report is provided by a Nigeria-based oil company who identity and data must be protected in line with the company's rules and regulations.

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